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# WAR MEDICINE AND SURGERY

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## WOUNDS OF THE CHEST IN WARTIME.

WAR wounds of the chest are serious injuries. They were the cause of death in 20% to 30% of the soldiers found dead on the battlefields in the Great War, and, in contrast to this, they were responsible for only 4% to 8% of the injuries among the wounded admitted to casualty clearing stations and frontline hospitals. It follows that the number of early deaths from these wounds must have been relatively high.

### First Aid and Early Treatment.

As with other wounds, the early treatment of hæmorrhage and shock is important, but, in contradistinction to the treatment of wounds in less vital parts, it may sometimes be necessary to give the local injury precedence. The thorax contains the heart and lungs, and interference with the function of these organs may threaten the life of the patient. The most common of the wounds requiring immediate attention is a large open pneumothorax, often referred to descriptively as the "sucking wound". The diagnosis of this is self-evident: air rushes in through the wound with inspiration, and out with expiration; the lung is alternately pushed into, and withdrawn from, the wound, spluttering blood-stained fluid as it moves, and the patient is dyspnoic and panic stricken. Wet pads and strapping may be used to close the wound temporarily, but have not proved successful when the patient has had to be transported some distance; they were tried in the early stages of the present war, but they tended to become ineffective when the position of the patient altered. The only successful way of closing these wounds is by suture, and this can be done without anaesthesia. Interrupted silk-worm gut sutures are passed deeply into the tissues, clearing the wound edges by about half an inch on each side. If the wound is a very large one portion of a field dressing can be placed in it and the stitches tied over the dressing as in an anchor dressing. A wound that is sutured roughly in this way under emergency conditions is liable to burst apart if infected, so that it should not be closed and forgotten; in favourable circumstances, the patient may reach a hospital in time for a formal excision to be carried out.

It is generally considered that patients with chest injuries do not stand transportation well. This is perhaps always true of transportation from the battlefield, but it has been pointed out that what really distresses the patient is the movement of his body on the stretcher, or movement from stretcher to stretcher, rather than movement of the ambulance. If the patient is carefully lifted into position and made comfortable with his trunk propped up at 30° to the horizontal, the journey itself is well tolerated. When London was first bombed intensively, patients with injuries to the chest were admitted to many hospitals scattered over the metropolitan area and treated in the admitting hospital. As experience grew it became the practice to retain in these hospitals only those who did not require early open operation; for example, patients with crush injuries. The remaining patients were treated for shock and then taken some twenty miles to special

centres for thoracic surgery.<sup>(10)</sup> It is generally agreed that patients with chest injuries should not usually be transported by air. The diminution in oxygen tension and, in some cases, the general diminution in pressure may prove harmful. This seems to be true even when the altitude attained is only about 5,000 feet.

Lockwood has pointed out that in the Great War about 50% of the patients with chest wounds died either on the field or before they had got any further back than the casualty clearing station.<sup>(11)</sup> He has entered a special plea for "that group of patients who assuredly will die within the first 48 hours if not dealt with surgically", and he asks for immediate recognition of the nature of the wound, prompt attention for hæmorrhage and shock and early evacuation. This raises the question of what types of thoracic wounds require early operation.

The answer to this problem differs according to the conditions. Operation of itself is insufficient; adequate after-treatment by a trained thoracic surgeon is of equal importance, and, unless this is available in a quiet and well-equipped centre, operation is often of no avail. Those with experience of surgery in mobile warfare such as occurred in the Middle East during the last few years are not in favour of early operation on patients with chest wounds. One Australian surgeon considers that, provided open wounds have been closed by the first medical officer to see them, there is only one important indication for early operation, namely, continued systemic hæmorrhage, which is usually from an intercostal artery or the internal mammary artery.<sup>(12)</sup> The British experience in the Middle East has supported this view, as the following quotation shows:<sup>(9)</sup>

In general the tendency of surgeons in the forward area has been to deal conservatively with chest cases and to do little more than close a sucking wound. The after-treatment has been repeated aspiration . . . blood transfusions . . . and sulphapyridine. Most cases seem to have done well on these conservative lines. Even when there is a retained foreign body of some size in the chest no early attempt has as a rule been made in the forward area to remove it. Surgeons feel that to attempt to remove a foreign body by an early thoracotomy in such a setting would be to court disaster.

Some figures given in a further article support these general statements. Among 2,500 battle casualties treated in the forward area, not one operation was performed primarily to deal with injury of the intrathoracic structures. Of 63 patients with penetrating chest wounds, only three developed an empyema.<sup>(13)</sup>

These opinions may be summed up in the statement that, under the conditions of warfare prevailing in the Middle East campaigns, early operation on patients with chest wounds was indicated mainly for progressive hæmorrhage from vessels in the thoracic wall and for open pneumothorax.

At the beginning of the present war surgeons advocated early open thoracotomy for penetrating wounds of the chest, especially those that caused laceration of the lung, and certain of those associated with the retention of foreign bodies. There are occasions when such operations are necessary; excision of any lacerated and contaminated wound is always advisable if the operation can be done

early and under satisfactory conditions; but the chest should never be opened lightly, since the operation is a hazardous procedure which may tax the resources of the most gifted surgeon, especially when there is inadequate provision for proper anaesthesia and for suitable instruments.<sup>(6)</sup> Moreover, the theoretical justification for these operations is less strong than it used to appear: it is now known that laceration of the lung is not a common cause of continued hemorrhage in patients who reach an operating theatre; if the laceration is peripheral, the wound usually seals itself as a result of pneumothorax and lung collapse; if the hemorrhage is from the great vessels at the hilum, death usually occurs before operation is possible; in practice, there are very few whose wounds lie between these two extremes and who are therefore likely to be saved by the closure of bleeding pulmonary vessels at operation.

As for the removal of foreign bodies, this can be deferred until the lung has healed. In the absence of infection, healing is fairly rapid owing to the good blood supply.

In war surgery early thoracotomy has therefore been superseded to some extent by repeated aspiration, supplemented, if necessary, by subsequent thoracotomy. This policy, of course, is quite different from the policy of complete conservatism which produced such disastrous results in the treatment of chest wounds during the first two years of the Great War.

It is well recognized, of course, that early surgical interference may be required for the following rather rare conditions: pressure pneumothorax, some cases of mediastinal emphysema, and some wounds of the heart. Further, thoraco-abdominal wounds mostly require operation, and they may be regarded as a variety of thoracic injury.

#### Classification of Chest Injuries.

A number of classifications have been suggested for injuries of the chest, but complications of chest wounds are so numerous and interrelated that these classifications are rather unsatisfactory.<sup>(7)</sup> Even the distinction between penetrating and non-penetrating injuries is often of little value, since essentially the same lesion may be produced by each. In this article the following varieties of chest injury are discussed: (a) fracture of the ribs; (b) pressure pneumothorax; (c) subcutaneous emphysema and mediastinal emphysema; (d) massive collapse; (e) traumatic asphyxia; (f) hemothorax; (g) penetrating wounds involving the lung; (h) wounds of the heart; (i) thoraco-abdominal wounds.

#### Fracture of the Ribs.

The simple fracture of a rib is usually not an important injury; it can be readily diagnosed by the sharp localized pain on respiration and tenderness on pressure, and can be treated by "Novocain" injection or by strapping. When several adjacent ribs are fractured, however, the condition referred to as "stove-in" chest occurs. This results most commonly from a crushing injury which compresses the chest in the antero-posterior diameter and causes fractures both anteriorly and posteriorly. A segment of the chest is consequently left without bony support. When inspiration occurs the affected part of the chest falls instead of rises; breathing is maintained chiefly by the action of the diaphragm, so that the abdomen protrudes as the chest sinks.

Immediate immobilization of the fractured ribs is necessary. Strapping is applied during full expiration so that it covers the wounded area and extends for three inches across the mid-line front and back. Due care must be taken when applying the strapping to see that the ends of the broken ribs are not forced through the skin or into the lung. When the injury is bilateral it may be necessary to hold the chest wall elevated by grasping two ribs on each side with towel clips and attaching the clips to an overhead frame or a loose plaster cast.

In the case of simple fractures no consideration need be given to the questions of reduction and union. The aim is to avoid the disturbance of respiration caused by instability of the chest wall and by pain. Attention may also be required for two complications: traumatic asphyxia,

which occurs, for example, after burial under the debris from air raids; and acute dilatation of the stomach, which may cause vomiting and inhalation pneumonia.

In war surgery compound fractures of the ribs are usually due to penetrating foreign bodies. These wounds must be excised so that bleeding from the intercostal vessels can be detected and controlled, and any indriven fragments of bone can be removed.

#### Pressure Pneumothorax.

Pressure pneumothorax results when a valve type of communication leads from the air of the pulmonary system to the pleural space. The air enters at first during ordinary respiration, and subsequently is forced in under pressure during coughing. Some authors believe that a similar condition can arise when there is a valved opening in the chest wall; others deny this; and in any case it is unlikely that a high positive pressure could be built up in such a way.

Pressure pneumothorax is sometimes made obvious by such manifestations as dyspnoea, hyperresonance, absent breath sounds and displacement of the heart to the opposite side. On other occasions the signs are more indefinite and the diagnosis is uncertain until a needle is inserted into the intrapleural space.

The immediate treatment is to pass a wide-bore needle (about number 14 gauge) through the second right intercostal space two inches from the sternum, and to release the air that is under pressure. The needle is connected by rubber tubing to a "water seal" in a bottle on the floor. When the pulmonary lesion is eventually closed off, air ceases to bubble through the water even when the patient voluntarily raises his intrapulmonary pressure.

It must not be forgotten that pressure pneumothorax can develop after the closure of an open pneumothorax. This is particularly liable to occur if a soldier's wound is closed in a forward area and he is neglected during evacuation.

#### Subcutaneous Emphysema and Mediastinal Emphysema.

Subcutaneous emphysema and mediastinal emphysema are caused by the escape of air from the pulmonary system into the subcutaneous tissue and the mediastinum, respectively. Subcutaneous emphysema is easily recognized by the crackling sensation which the air gives on pressure with the fingers. If the patient has a bout of coughing the emphysema may spread widely to the neck and face, but the condition is, nevertheless, relatively harmless. Mediastinal emphysema may exert pressure on the thin-walled great veins and rapidly cause dyspnoea, circulatory disturbance and death. It is diagnosed by (a) a crackling sensation felt on pressure over the suprasternal notch; and (b) crepitations heard over the sternum, synchronous with the heart beat, and present when the subject holds his breath. If it is recognized as the cause of symptoms, a transverse incision should be made in the suprasternal region, the distended veins of the neck being carefully ligated, and a finger should be introduced to evacuate the air bubbles. A tube is left to provide a permanent escape for the air. The treatment is not always successful owing to the inaccessibility of some of the emphysematous bubbles.

#### Massive Collapse of the Lung.

Massive collapse may result from foreign bodies in the bronchi and also from any painful injury, whether penetrating or non-penetrating. The patient has dyspnoea and cyanosis, and there are absence of lung resonance and diminution or absence of breath sounds on the affected side. The heart and mediastinum are drawn towards the side with the lesion.

The patient should be placed with the affected lung uppermost and encouraged to cough. Morphine and sedatives should be withheld. If simple measures fail, a bronchoscope should be passed and the foreign body or mucus sought and removed. In a surprisingly large number of cases the collapse will disappear following the aspiration of only a small amount of mucus from the orifice of the affected bronchus. If the collapse cannot be corrected, sulphonamide drugs should be given prophylactically to prevent pneumonia.

### Traumatic Asphyxia.

Sudden compression of the thorax causes violent expression of blood from the right side of the heart and the great veins of the neck back into the small venous channels. The blood remains in these vessels for some time, the exact cause of the stasis being unknown. The skin and mucous membranes of the head and neck become bluish-violet and congested with blood.

Treatment is by rest and oxygen. The discoloration starts to fade at about the second day and usually disappears in two weeks. As a rule patients are quite comfortable and the majority have no serious after-effects.

### Hæmothorax.

Hæmothorax or hæmopneumothorax may be a complication of any severe thoracic injury, penetrating or non-penetrating; it is naturally more common in the former type, in which it occurs in about 75% of all cases. The apparent severity of the wound is no indication of the probable size of the effusion. The hæmothorax may be described as: (a) simple, when there is no evidence of gross damage to the chest wall or lung; and (b) compound, when such damage exists or a foreign body is present. Either may become infected.

#### Simple Hæmothorax.

The findings on physical examination of a simple hæmothorax may be anomalous, but they are used whenever possible to assess the size of the effusion. The best evidence on this point, however, comes from radiographic examination which shows displacement of the heart and elevation of the diaphragm. The fact that the diaphragm rises on the injured side indicates that there has been a decrease in intrathoracic pressure and suggests that the collapse of the lung is, as it were, active and not the result of the hæmorrhage. In other words, the atelectasis, by closing off bleeding pulmonary vessels, helps to determine the size of the hæmorrhage, rather than being itself determined by pressure from the effusion. The explanation of the collapse of the lung is not clear; it may be due to plugging of the bronchus, since in certain cases it occurs in the contralateral lung.

Blood in the pleural cavity usually remains more or less fluid; sometimes there is a partial clotting in the form of a deposition of fibrin on the walls of the cavity, but a true massive clot is rarely found.

The treatment of simple hæmothorax is early and repeated aspiration. It is considered that after about forty-eight hours there is not much danger of restarting the hæmorrhage by removing the fluid. A site is selected at about the seventh or eighth intercostal space in the posterior axillary line, although the amount of ascent of the diaphragm must be taken into account in choosing the spot. Local anaesthesia of the chest wall and pleura is secured and a wide bore aspirating needle is passed into the pleural cavity. The needle should be fitted with a stop cock to prevent the uncontrolled entrance of air while the syringe is being emptied. If it is desired to admit air deliberately, this can be done through the fourth intercostal space in the anterior axillary line by means of an artificial pneumothorax apparatus. The admission of air enables the aspiration to be done more readily; should infection supervene, however, an expanded lung would help to localize it, whereas a lung which has been made to collapse by artificial pneumothorax would favour its spread. Some advise that air should be introduced only if the patient complains of a tight feeling in the chest during aspiration or if excessive force is required to withdraw the blood.

#### Compound Hæmothorax.

If a hæmothorax rapidly refills after aspiration it is likely that the bleeding has come from an intercostal or internal mammary artery. The intercostal arteries are so well protected by bone that they are not likely to be injured unless the rib is fractured; a knowledge of this fact assists in diagnosis. The best method of dealing with a torn intercostal artery is to expose the bleeding point by resecting a couple of inches of rib and to ligate the vessel. When circumstances do not permit a careful

exposure of the vessel a circumcostal suture is tied on each side of the bleeding point; this usually stops the hæmorrhage, but sometimes, apparently, the vessel is too well protected in the subcostal groove to be ligated in this way. The internal mammary artery is situated about half an inch lateral to the edge of the sternum. Laceration of this artery may produce death in a few hours; bleeding occurs from both of the cut ends, so that both have to be ligated.

A hæmothorax may also be considered "compound" when associated with lacerations of the lung, retained foreign body, and open pneumothorax. Early thoracotomy may sometimes be performed for the first two of these complications, but only if the following conditions are fulfilled: (a) the patient can be operated on within about six hours of injury; (b) shock has been effectively treated; (c) an expert anaesthetist is available and proper instruments are at hand; (d) the surgeon is trained in thoracic surgery; (e) the patient is assured of skilled post-operative treatment; and (f) the surgeon is convinced that immediate operation will give better results than repeated aspiration and subsequent operation.

**Infected Hæmothorax.**—The most important complication of hæmothorax is infection. It is common for pyrexia to be present at the onset of the hæmothorax, and apart from an occasional slight secondary exacerbation, to subside steadily in about four days. This rise of temperature is a normal finding and, therefore, in detecting the development of infection, the temperature is of less importance than the pulse or respiratory rate.

When infection occurs in a hæmothorax the correct treatment, in the early stages, is repeated aspiration and not the insertion of a drainage tube. The latter can be used when the infection has become localized, but if it is employed too early there is a risk that air will be admitted, resulting in pulmonary collapse and a total pyopneumothorax.

It is desirable to give a generous diet when treating an extensive infection such as a pyohæmothorax.

### Penetrating Wounds Involving the Lung.

**Examination.**—Clinical examination is reduced to a minimum so as to avoid disturbing the patient unduly. Even the taking of a skiagram is by no means imperative; it can often be deferred until the patient's condition has improved. The information which it eventually provides is, however, very valuable; one discovers the size and position of the foreign body, if any, the amount of blood and air in the pleural cavity, the position of the mediastinum and the diaphragm, and the amount of damage done to the skeletal structures.

**Clinical Course.**—The clinical course of a penetrating wound, closed when necessary as a first-aid measure and treated conservatively, may follow one of four types.<sup>(1)</sup>

1. Blood and air enter the pleural cavity at first, but the hæmorrhage ceases when lung collapse occurs. The cause of the collapse is debatable, but as a result of the cessation of bleeding the patient's condition gradually improves. If simple treatment by aspiration is carried out, at the end of seven days temperature, pulse and respiration have returned to normal.

2. The patient appears to be holding his own after twelve to eighteen hours and then a deterioration occurs owing to the rapid formation of pleural exudate. If the fluid is aspirated before the condition is too advanced, the results are satisfactory.

3. The patient steadily deteriorates because of a continued hæmorrhage from a systemic vessel. Death will occur unless the vessel is tied off.

4. The patient develops a pressure pneumothorax.

Evidence has already been given that the course of the majority of patients treated by conservative methods is favourable. In some cases, however, the indications laid down for early thoracotomy may be present.

**Anæsthesia for Thoracotomy.**—The requirements for anæsthesia for thoracotomy are that there should be a small respiratory excursion, no anoxæmia, and no fall in blood pressure. A method favoured in America is the use of positive pressure anæsthesia in which the lungs are kept inflated by maintaining a pressure of six to eight



centimetres of water. Some British authorities advocate the method of controlled respiration. The patient wears an air-tight mask which is connected to an expansile bag controlled by the hand of the anaesthetist. The anaesthetist controls the degree of aeration and can arrange normal respiration even with the patient's chest wide open; there is no paradoxical respiration or mediastinal flutter; movement of the lungs can be diminished or even stopped for a minute while the surgeon makes some exact manoeuvre; the lung can be occasionally inflated during operation and expanded at the completion of the intrathoracic surgery; a plentiful supply of oxygen is assured and carbon dioxide is removed by an absorber.

It is possible to perform even an extensive thoracotomy under local or spinal anaesthesia.<sup>(6)</sup>

**Technique for Thoracotomy.**—The entrance and exit wounds are excised. The most difficult wounds are those that involve the muscles beneath the scapula; in some cases it may be necessary to raise the scapula in order to obtain free access. Once the wound is excised it can sometimes be used as an approach to the lung; otherwise a fresh incision is made over the postero-lateral aspect of the seventh rib and an intercostal space opened above or below this rib, according to the most likely site of the intrathoracic damage. The wound is retracted widely and the blood removed from the intrapleural space. The lung is then dealt with: lacerated pulmonary tissue is excised and foreign bodies are removed; tears in the lung are sutured. When the laceration is gross it may be necessary to perform lobectomy.

Closed drainage with a water seal is always employed, and is maintained for about forty-eight hours. Since the objects of treatment are to achieve healing of the wound and air-tight drainage of the chest, drainage should be carried out at a site of election and not through the original wound. A stab wound is made posteriorly in the ninth intercostal space to transmit the drainage tube.

The surgical incision in the chest wall is sutured in layers. The original wound also has to be closed, in spite of the general warning that war wounds should never be sutured primarily. It is a case of balancing the possible danger of sepsis against the certain danger of open pneumothorax.<sup>(7)</sup> A compromise should be made if the excision has not been thorough; in this case the wound is made air-tight with a pad. The same procedure has to be followed in wounds that are too big for closure.

**Delayed Thoracotomy for Treatment of Empyema or Removal of Foreign Bodies.**—If a penetrating wound has been treated conservatively by aspiration and empyema develops, the treatment is the same as for empyema of other aetiology. The conditions are usually favourable for operation by about the second week.

The best method of dealing with foreign bodies is to wait three to eight weeks, by which time the patient is able to withstand operation with a minimum of risk and disability.<sup>(8)</sup> Not all foreign bodies require removal. Those of less than half an inch diameter that have passed through an intercostal space are unlikely to cause suppuration and are best left alone; multiple foreign bodies and those near the hilum, or in any other part from which removal is technically difficult, are also ignored.<sup>(9)</sup>

The foreign body is localized by skiagrams or by fluoroscopy. It is approached by the shortest feasible route. If it is in the mediastinum care should be taken to avoid incising the pleura. If it is in the lung a direct approach can be made when adhesions are present, but otherwise the lung is made to collapse by artificial pneumothorax and the foreign body easily picked out. The method of using artificial pneumothorax has many advantages; the disturbance caused by the operation is minimal; there is little likelihood of mediastinal flap; the finding of the foreign body is simplified; and the amount of bleeding is small. The foreign body is palpated in the collapsed lung; and the smallest possible amount of tissue overlying it is incised; the foreign body is then removed, the incision sutured, and negative pressure drainage instituted. By about one week after operation the temperature has returned to normal and exercise of the thoracic muscles may be undertaken. The patient is fit to resume duty about two and a half months after operation.

### Wounds of the Heart.

Wounds of the heart are fatal in the great majority of instances, but some patients can be saved by prompt attention.<sup>(10)</sup> A penetrating wound of the heart or of the intrapericardial great vessels causes haemorrhage into the pericardial sac. This interferes with further movement of the heart and results in cyanosis, engorgement of veins in the neck, faint heart sounds and low blood pressure.

Temporary help may be given by aspiration of the pericardium, the needle being inserted in the angle between the xiphoid process and the left costal arch, and directed cranially, posteriorly and towards the left. This conservative treatment is often the safest; but if the absence of heart movement can be established by fluoroscopy, pericardotomy and suture of the heart wound are carried out. The anaesthesia should be either the positive pressure or "controlled respiration" type. A curved incision is made over the third, fourth and fifth left costal cartilages, and sufficient of these is removed to expose the underlying pericardium. Opening of the pleura is to be avoided. Wounds of the heart are sutured with fine silk sutures which emerge about a quarter of an inch from the edges of the wound.

Trauma to the intact chest may be transmitted to the heart and result in reflex spasm of the coronary vessels, contusion or actual rupture. The results of contusion may not be apparent until a couple of weeks later, when there may occur disorders of conduction, coronary infarction or cardiac rupture. Because of this latent period, any patient who has had a severe non-penetrating injury of the heart should have absolute rest for at least three weeks.

### Thoraco-Abdominal Wounds.

Thoraco-abdominal wounds were relatively common in the Great War of 1914-1918 and in the recent Spanish Civil War.<sup>(11)</sup> They had a high mortality; the prognosis was worse if the missile entered by the abdomen rather than the thorax. It was also worse when the left side was involved, presumably because of the greater danger of injuring a hollow viscus.

The treatment varies according to the relative severity of the thoracic and abdominal wounds. If the thoracic wound is small, the abdomen should be opened and the thorax treated conservatively. If the thorax requires exploration, it should be dealt with first and the upper part of the abdomen approached through the diaphragm. The repair of diaphragmatic tears is essential. Wounds of the right lower part of the thorax or the right hypochondrium do not often require operative treatment.

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